PROPERTIES OF SOILS AND THEIR IMPLICATIONS IN THE
RECLAMATION OF LANDS DISTURBED BY MINING

by

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INTRODUCTION

Traditional definitions of soil often involve the phrase "natural medium for the growth of land plants". The differing properties of soils are attributed to the integrated effect of climate and biological mechanisms acting upon geologic material as conditioned by relief over time. In the Canadian System of Soil Classification (1978) naturally occurring soils include those disturbed by activities such as cultivation and logging but do not include man-displaced materials such as gravel dumps and mine spoils.

Natural soil extends from the surface to the depth at which soil forming processes can no longer be detected; therefore, a "non-soil" underlies unconsolidated material which has not undergone pedogenic processes. A more encompassing definition is given in the American System of Soil Classification "Soil Taxonomy" (1975), which states: "Soil...is the collection of natural bodies on the earth's surface, in places modified or even made by man, of earthy materials containing living matter and supporting or capable of supporting plants out of doors." This definition includes drastically disturbed materials such as mine waste deposits.

I prefer this latter wider definition; however, in this paper soil includes that which occurs naturally as defined by the Canadian System and also the deeper surficial deposits not affected by soil forming processes. I believe that these deeper "non-soil" deposits often provide the most economic medium for reclaiming lands disturbed by mining.

My literature search indicated that research has been focused on the properties of mine waste materials and on the opportunities for
reclaiming these lands using soil amendments and various leaching processes. Much less information is available concerning the use of naturally occurring soil as a source of cover to aid the reclamation process. It seems logical to me to use naturally occurring soil instead of trying to create a medium for plant growth from mine wastes in a fraction of the time it took Mother Nature to create soil. Recent legislation in some areas of North America stipulates that naturally occurring soil material in the area to be mined must be moved and stored for reclamation of the mine site. The limited amount of information concerning this innovation suggests that positive results were obtained, however, two areas of concern expressed were cost effectiveness and contamination problems at the soil-spoil interface.

SOIL MAPPING

A recent paper in Reclamation of Drastically Disturbed Lands states: "There should be an engineering dictum that advance planning is essential to success in major disturbance activities. It is inconceivable that a responsible engineer would start building a highway, an urban mall or a surface mine without some appraisal of the rock and soil to be disturbed or used" (Smith and Sobek, 1978). Accordingly, for any mining project an up-to-date soil survey at a suitable level of detail should be incorporated into the planning process at the earliest stage possible. This soil survey will provide base data for the reclamation of disturbed lands and for ancillary developments such as energy and transportation corridors, plant sites and housing developments.

LEVEL OF DETAIL

Soil surveys can be carried out at three levels of intensity. Reconnaissance soil surveys are regional in scope and the mapping scale is generally 1:50,000 (2 cm = 1 kilometre) or smaller. Semi-detailed
surveys are often still regional but can be effective during the early planning stages even for area specific purposes. The scale of semi-detailed surveys generally ranges from 1:20,000 to 1:40,000 (5 cm = 1 kilometre to 2.5 cm = 1 kilometre). Detailed soil surveys are used for site specific planning and are generally 1:10,000 (10 cm = 1 kilometre) or larger. The level of site inspection undertaken during these different soil surveys increases proportionately to the scale of the survey.

Selection of an appropriate mapping scale and intensity of survey depends on the purposes of the survey. Generally speaking for such things as corridor selection for linear developments like road location, the map scale should be at least 1:25,000. For delineating bodies of soil suited to stockpiling for reclamation, a mapping scale of at least 1:10,000 is necessary. As a general guide one should keep in mind the area represented by a 1 cm square at a given mapping scale. At 1:50,000 a 1 cm square area covers 25 hectares and at 1:10,000 1 cm square covers 1 hectare.

MAPPING METHODOLOGY

The first step in creating a soil map is to obtain the most recent aerial photographs available at a scale which approximates that of the maps to be produced. The aerial photographs are pre-typed through stereoscopic interpretation and by using any information on the geology and soils of the area. Pre-typing generally involves the delineation of the preliminary mapping units according to landforms and materials. The terrain classification system of the E.L.U.C. secretariat in 1976 can be used to pre-type aerial photos of B.C. landscapes. Figure 1 shows an aerial photograph at a scale of 1:20,000 which has been pre-typed and classified using the terrain classification system prior to field mapping. Note the use of wing points and correlation to the flightlines above and below. These are useful in the field and are time savers. Preliminary site locations are laid out according to the
Figure 1

AERIAL PHOTOGRAPH (SCALE 1:20,000), PRE-TYPED AND CLASSIFIED
mapping unit delineations on the photograph so as to arrive at representative sites at a reasonable level of field checking.

The field program includes site location using the pre-typed photographs and whatever means of transportation is necessary. Site classification involves the description of environmental features including the terrain, vegetation and soil. The Resource Analysis Branch of the Ministry of the Environment has compiled complete site, soil profile and vegetation description forms in their *Manual for Describing Ecosystems in the Field* (1980, in print).

Soil pit excavation is a topic very dear to my heart considering all the layers of skin that I have removed over the years trying to bang down a soil pit in very unfavourable conditions. During most of my recent survey work attempts have been made to use a regular backhoe where access allows, or a climbing backhoe in more difficult terrain. It saves your hands and time, moreover, the end product gives much more detail as to the variability of the soil profile and its changes with depth. A tractor and power-auger is also adaptable where the terrain and soils are suitable. The amount of information obtainable using the power-auger is not as extensive as that using the backhoe because of the small pits and mixing of materials, however it is a useful method for checking variability of deposits. Considering that access to most of the potential mine areas in the province may limit excavation to the hand method, it is essential that sufficient manpower and time is made available to excavate pits of adequate size and depth so that soil variability with depth can be ascertained.

Soil classification should be in accordance with the *Canadian System of Soil Classification*, 1978. Although much of the classification is Greek to most non-soils people, it is important information to the pedologist who must make sound interpretations.

The selected mapping base depends on the preference of the users. Most engineers like planimetric maps with contours, whereas, many soils
people choose a controlled photo mosaic or orthophoto compiled from the aerial photography. Mapping legends will depend on the users needs. For the base soil map, I prefer a fairly detailed and comprehensive legend followed by the preparation of derivative maps which present suitability interpretations for various uses.

No soil survey is complete without a sampling program and laboratory analyses. The sampling program design is important because samples must be representative of the various soil types in the project area. The analyses should meet the needs and objectives of the survey. The pedology laboratory of the Department of Soil Science at U.B.C. has compiled a Methods Manual (1977) applicable to the B.C. situation. This laboratory as well as other private and governmental labs are able to carry out the analyses.

SOIL PROPERTIES

Soils possess unique physical and chemical characteristics which influence their behaviour under varying conditions. Soils are generally separated into mineral and organic categories. The following discussion is general in scope and addresses only those soil properties important in mine waste reclamation.

MINERAL SOILS

Mineral soils contain less than 30% organic matter by weight.

Physical Properties
These soil properties affect both the engineering behaviour of the material as well as plant growth. The physical characteristics significant to the use of soils in mine waste reclamation are discussed
under two headings: "Inherent Characteristics" and "Behavioural Characteristics".

Inherent Characteristics

Particle Size Distribution - This refers to the grain size distribution of the whole soil including the coarse fragments. The Canadian System of Soil Classification (1978) uses the term texture to refer to the fine earth fraction (less than 2 mm) of the soil. The relative percentages of sand, silt and clay comprising the fine earth fraction are used to determine soil texture. Figure 2 depicts a soil texture triangle and shows the relative proportions of sand, silt and clay in the various textural groupings. Using this system, soil textural classification is generally modified by such terms as gravelly or cobbly to indicate the coarse fragment content. For mapping soils at the family and series level the Canadian System establishes 11 particle size classes on the basis of coarse fragment size and content as well as on textural analysis.

Bulk Density or Volume Weight - This is defined as the mass of dry soil per unit bulk volume and is probably the most important single factor influencing the engineering parameters of soil (USDA, SCS, 1975). In general terms, soil strength increases with increased density while permeability and compressibility generally decrease. The bulk density of a soil is increased by compaction and consolidation under heavy loads.

Soil Structure - This is defined as the arrangement of the soil separates into secondary units called peds. These peds are often arranged in a distinctive characteristic pattern in the soil profile. Soil ped classification is based on size, shape and degree of distinctness according to the Canadian System of Soil Classification (1978). Soil structure is indicative of both physical and chemical characteristics of a soil and influences management practices in varying degrees.
Proportions of Soil Separates in Various Soil Textural Classes

1) SOIL TEXTURAL CLASSES ARE GROUPED AS FOLLOWS:

- **Coarse textured** - sand, loamy sand, sandy loam.
- **Medium textured** - very fine sandy loam, loam, silt loam, silt
- **Fine textured** - sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, clay,

<table>
<thead>
<tr>
<th>SEPARATE</th>
<th>DIAMETER (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>0.05 - 2.0</td>
</tr>
<tr>
<td>Silt</td>
<td>0.002 - 0.05 &lt;</td>
</tr>
<tr>
<td>Clay</td>
<td>0.002</td>
</tr>
</tbody>
</table>
Behavioural Characteristics

Many soil behavioural characteristics are recognized in the engineering field manual of the USDA, SCS, (1975). Only those characteristics considered most important to mine reclamation are described below.

**Plasticity** - This is the most important attribute of fine grained soils in terms of engineering behaviour. Soils with a high plasticity generally have a higher cohesion and resistance to surface erosion, piping, and cracking than soils with lower plasticity. The plastic limit is the water content corresponding to an arbitrary limit between the plastic and semi-solid states of consistency of the soil. This limit is determined by the water content at which a soil will just begin to crumble when rolled into a thread of approximately 1/8 inch in diameter.

**Liquid Limit** - This is the second most important behavioral characteristic of fine grained soils. It is defined as the water content corresponding to an arbitrary limit between the liquid and plastic states of consistency of the soil. It is determined by the water content at which a pat of soil cut by a groove of standard dimensions will flow together for a distance of 1/2 inch under the impact of 25 blows in a standard liquid limit apparatus. Both clay and silty materials may have either high or low liquid limits.

The difference between the liquid limit and the plastic limit is termed the plasticity index, and it defines the range over which the soil exhibits plastic properties. The plasticity index is used to classify soils according to the unified system used by soil engineers.

**Available Water Storage Capacity** - This is considered by most to represent that portion of water in the soil readily available for plant use. It is defined as the difference between the amount of water in the soil at field capacity and that in the soil at the permanent wilting point of most plants. Figure 3 gives an approximation of the
Approximation of Available Water Storage Capacity
available water storage capacity of soils according to texture and coarse fragment content. The important inference here is that medium textured soils (loam to silt loam) have the highest available water storage capacity, whereas, for fine textured soils (silty clay loam to clay), the available water storage capacity decreases with the degree of fineness. Similarly, water storage capacity decreases with increasing coarse fragment (CF) content.

**Permeability** - This is a soil property that allows the transmission of water and air. Permeability is measured as the rate at which water is transmitted under saturated conditions and can be equated with saturated hydraulic conductivity. Permeability can be estimated from soil characteristics observed in the field such as texture, structure and soil pores. Generally, permeability increases as grain size increases and decreases as density increases.

**Consistence** - This indicates the resistance of the soil peds to deformation and is a factor of the degree of cohesion of the soil particles. Consistence is described according to the moisture content of the soil under dry, moist and wet conditions. Consistence influences the ease of excavation as well as handling and management of a disturbed soil.

**Erosion** - This is defined as the wearing away of the soil surface by water, wind, ice and other processes. Soil susceptibility to both surface and internal erosion (piping) is critical to the reclamation process. Generally, soils with a high susceptibility to surface erosion have a high susceptibility to internal piping. This is in contrast to low susceptibility soils which are generally more plastic and not as susceptible to surface or internal erosion.

Many other important behavioural characteristics of concern to soil engineers should be considered in the use of soils for mine waste reclamation. Basically geotechnical, they include compressibility, shrink–swell and bearing capacity.
Chemical Properties

These soil characteristics affect both the engineering behaviour and plant growth. The following briefly discusses some of the more important chemical characteristics of mineral soils.

Reaction - This is defined as the degree of acidity or alkalinity of the soil and is expressed in terms of pH. Descriptive classes for pH range from extremely acid at pH's less than 4.5 to very strongly alkaline at pH's greater than 9. Reaction influences soil corrosivity and is therefore important in engineering considerations and also strongly influences plant growth. Plants generally have a narrow range of pH tolerance although some plant species are pH specific.

Salinity - This is defined as the amount of soluble salts in the soil and is expressed in terms of electrical conductivity of the soil saturation extract in mmhos per cm at 25° centigrade. Salinity affects the suitability of a soil for plant production as well as stability for construction purposes and corrosivity to metals and concrete.

Cation Exchange Capacity (CEC) - This is defined as the total amount of exchangeable cations that a soil can absorb and is expressed in milliequivalents per 100 grams of soil. The cation exchange capacity of a soil is an index of its inherent nutrient holding capacity and is markedly influenced by organic matter content, the amounts and kinds of clay present, and, to a more limited extent, the pH of the soil. Generally, finer textured soils have a higher cation exchange capacity than coarse textured soils and, within a particular textural class, organic matter content and the amount and kind of clay present influences the CEC.

Fertility Status

To ensure plant growth, an adequate supply of nutrients must be maintained in the soil medium. For reclamation purposes, the physical and chemical characteristics of soils discussed previously are adequate for
the assessment of nutrient holding capacity. However, for successful plant growth, the availability and proportion of plant nutrients must be known for proper maintenance of the reclaimed area.

**Plant Nutrients** - Plants obtain sixteen essential elements from the soil, three of which are commonly deficient and are therefore referred to as primary nutrients. These are nitrogen, phosphorus, and potassium. Calcium, magnesium, and sulphur are secondary nutrients which are less often deficient in soils. Plant growth in soil will be retarded if any of these elements are absent, insufficient, or unbalanced with the supply of other nutrients. These elements are commonly supplied in the form of commercial fertilizers.

Micro-nutrients or trace elements are those taken up by the plants in very small quantities. These include iron, manganese, copper, zinc, boron, molybdenum, chlorine, and cobalt. They are just as essential to plant growth as the other nutrients, but are required in much smaller amounts. Micro-nutrient uptake is often a problem in coarse textured soils, organic soils, or soils having extreme reaction.

**Toxicities** - Many of the micro-elements in excessive amounts may be toxic to plants. As an example, excessive copper has been shown to depress the uptake of iron by plants, which lead to symptoms of iron deficiency (Tisdale and Nelson, 1969). In B.C. soils other toxicities may arise due to relatively high levels of manganese, molybdenum, boron, and selenium. Soil analysis should be carried out prior to the use of any material in mine reclamation. The analysis should include trace element detection particularly for any element expected to occur in relatively high amounts, based on knowledge of the regional geology and soil types.
ORGANIC SOILS

These soils are recognized at the order level prescribed in the Canadian System of Soil Classification. They are described as soils derived dominantly from organic deposits and by definition contain more than 30% organic matter by weight. Most of the soils commonly referred to as peat, muck or bogs are included in the organic order. Such soils are usually water saturated during most of the year, occur in wet depressional areas, and are derived from hydrophytic vegetation. However there are exceptions, some organic soils comprise organic matter accumulated on steeply sloping, well drained, forested sites.

Under the Canadian System of Soil Classification organic soils are classified according to their degree of decomposition. For example, fibrisols are composed dominantly of relatively undecomposed fibric materials, mesisols are dominantly semi-decomposed mesic material; and humisols are dominantly well humified broken down organic materials.

Organic soils often make poor construction materials, and they require specific handling if used in the reclamation process. I wish to emphasize organic soils because of the tremendous number and variety of such deposits throughout B.C., particularly in mining areas. There is tremendous potential for utilizing these deposits as a soil amendment during reclamation, to increase the soil's cation exchange capacity and available moisture, to lower bulk density and help maintain desirable pH levels.

SOIL SUITABILITY FOR RECLAMATION

The suitability of soil for reclamation is determined from soil survey and analytical data. This determination should be carried out not only for soil in the area of the mine site, perhaps the most important area, but also for the surrounding environs. The approach described follows the Guide for Interpreting Engineering Uses of Soils USDA, SCS (1971).
This document contains a guide table for establishing suitability ratings of soils to be used as topsoil.

In many parts of North America, particularly in the Great Plains area, this type of assessment would be adequate for determining whether or not a surface soil should be stockpiled for use during the reclamation. Most of the Prairies are relatively flat, have fairly homogeneous soils belonging to the Chernozemic (grassland) order, and have fairly deep topsoil layers composed essentially of mineral materials complexed with organic matter. However, in many B.C. mining areas, topsoil does not exist or, if it does, it is very shallow in depth and limited in extent. There are not many B.C. locations that I can think of where it would be feasible, especially in the economic sense, to strip and conserve true topsoil material. Undoubtedly there are exceptions such as in parts of the Okanagan where a fairly extensive cover of Chernozemic soils exhibit some deep Ah horizons suitable for stockpiling.

The approach that should be taken is to assess the surficial material, including the surface and subsurface unconsolidated soil material, to determine its usefulness for the reclamation of mine waste. For a specific location it might be feasible to stockpile topsoil; but for other locations where that is not feasible, it may be worthwhile to stockpile surficial deposits that have the characteristics of a potentially suitable cover material.

Table 1 is a modification of the topsoil suitability guide referred to earlier. It represents an attempt to identify the various soil characteristics which affect the use of the material for mine waste reclamation and to establish limits as to the degree of soil suitability for use as a cover material. This table is only a general guide and may or may not be applicable in specific mining areas. It certainly could be much more elaborate. For example, the textural classes used could be replaced by unified soil classes and other behavioural characteristics could be identified according to their type.
### Table 1

**SUITABILITY RATINGS OF SOILS AS SOURCES OF COVER MATERIAL FOR MINE WASTE RECLAMATION**

<table>
<thead>
<tr>
<th>ITEM AFFECTING USE</th>
<th>DEGREE OF SOIL SUITABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GOOD</td>
</tr>
<tr>
<td></td>
<td>SL</td>
</tr>
<tr>
<td></td>
<td>SC</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Texture</td>
<td>SL</td>
</tr>
<tr>
<td></td>
<td>SC</td>
</tr>
<tr>
<td>Moist Consistence</td>
<td>&lt;15%</td>
</tr>
<tr>
<td>Coarse Fragment Content</td>
<td>non-stony, slightly stony</td>
</tr>
<tr>
<td></td>
<td>(classes 0,1)</td>
</tr>
<tr>
<td>Stoniness Class</td>
<td>not limiting if better than poorly drained</td>
</tr>
<tr>
<td>Drainage Class</td>
<td>&gt;100 cm</td>
</tr>
<tr>
<td>Thickness of Material</td>
<td>Soluble Salts (Electrical conductivity)</td>
</tr>
<tr>
<td>Reaction Class (pH in water)</td>
<td>slightly acid to mildly alkaline (6-8)</td>
</tr>
<tr>
<td></td>
<td>mildly alkaline (7.5-8)</td>
</tr>
<tr>
<td>Cation Exchange Capacity</td>
<td>&gt;25</td>
</tr>
</tbody>
</table>
and degree of limitation. Similarly, other factors such as available water holding capacity could be included. It should be noted that the table gives only estimates of the degree of soil suitability. Although it would be preferable to have a "good" soil material available, it may be that in some cases only soils rated "poor" in the table are available. Nevertheless, they are still suitable for reclamation, and despite their low degree of suitability, various soil amendments and management practices could be used to alleviate their limitations.

Figure 4 represents a portion of a soil map compiled from the aerial photograph shown in Figure 1. This area was mapped at a scale of 1:20,000 and I have used it as an example of the type of information that might be presented from a soil survey during mine site planning. Seven mapping units and two sub-components were established. Table 2 shows a simplified legend that might accompany this type of map and indicates the characteristics of the mapping units and rates the soil in terms of its suitability as a source of cover material.

Based on adequate soil survey information, an assessment of the surficial material at the mine site as a source of suitable cover material for mine waste reclamation, and the decision on whether or not to stockpile material can both be made. Also consideration should be given to the mapping and evaluation of all suitable materials surrounding the mine site. They may be potential sources of mine waste cover material. This cover will provide a medium better suited to plant growth and the development of a self-sustaining vegetative community than mine waste materials without such cover.

**SUMMARY**

At the Second Annual British Columbia Mine Reclamation Symposium held in Vernon in 1978, J.U. MacDonald, the senior reclamation inspector for the B.C. Ministry of Energy, Mines and Petroleum Resources stated: "Reclamation in British Columbia cannot be defined by a set of regula-
Figure 4

SOIL MAP COMPILED FROM AERIAL PHOTOGRAPH IN FIGURE 1

1:20,000 SOIL MAP - BIG LAKE
Table 2
SIMPLIFIED LEGEND FOR USE ON SOIL MAPS

<table>
<thead>
<tr>
<th>MAPPING UNIT</th>
<th>TERRAIN</th>
<th>TEXTURE</th>
<th>SOIL DRAINAGE</th>
<th>SOIL CLASSIFICATION</th>
<th>SIGNIFICANT CHARACTERISTICS</th>
<th>SUITABILITY AS SOURCE OF COVER MATERIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>morainal blanket</td>
<td>C CL</td>
<td>MW</td>
<td>BR.GL</td>
<td>highly compacted ground moraine at depths 100 cm</td>
<td>poor</td>
</tr>
<tr>
<td>1A</td>
<td>morainal blanket</td>
<td>C</td>
<td>MW</td>
<td>GL</td>
<td>severe erosion, rapid runoff</td>
<td>nil</td>
</tr>
<tr>
<td>1B</td>
<td>morainal blanket</td>
<td>C</td>
<td>MW</td>
<td>BR.GL</td>
<td>pitted and hummocky capping of GS veneer</td>
<td>poor</td>
</tr>
<tr>
<td>2</td>
<td>morainal blanket</td>
<td>GSL</td>
<td>W</td>
<td>BR.GL</td>
<td>inclusions of coarse textured morainal veneer</td>
<td>fair</td>
</tr>
<tr>
<td>3</td>
<td>morainal blanket</td>
<td>SCL</td>
<td>W</td>
<td>BR.GL</td>
<td></td>
<td>good</td>
</tr>
<tr>
<td>4</td>
<td>glaciofluvial veneer</td>
<td>VGS</td>
<td>W-R</td>
<td>O.DYB</td>
<td>excessively stony and gravelly</td>
<td>poor</td>
</tr>
<tr>
<td></td>
<td>over morainal blanket</td>
<td>SCL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>glaciofluvial blanket;</td>
<td>GS</td>
<td>R</td>
<td>O.DYB</td>
<td>moderately stony</td>
<td>poor</td>
</tr>
<tr>
<td></td>
<td>ridged</td>
<td>SCL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>organic</td>
<td>MESIC</td>
<td>VP</td>
<td>TY.M</td>
<td>inclusions of well humified forms and calcareous layers</td>
<td>nil but use-ful as soil amendment</td>
</tr>
<tr>
<td>7</td>
<td>morainal veneer over</td>
<td>GCL</td>
<td>W-R</td>
<td>O.DYB</td>
<td>morainal veneer is discontinuous</td>
<td>fair</td>
</tr>
<tr>
<td></td>
<td>glaciofluvial blanket</td>
<td>GCL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
tions or legislation because of the extreme variances of physiography, biogeoclimatic zones and elevations. We have mines in the dry belt of the Okanagan, the rainbelt of the coast having 240 inches of rainfall a year, elevations of up to 7,000 feet and in nearly all cases little or no topsoil." I agree with the first part of his statement and, if by the term "topsoil" Mr. MacDonald means deep organic mineral horizons suitable for crop growth, I agree with the whole. However, if he is implying that there is very little if any soil suitable for use in reclamation present within the mine sites of B.C. then I take exception.

I have mapped soils ranging from the Canada/U.S.A. border north to Fort Nelson and from elevations at sea level all the way up to some 3,500 masl, and I think many of us would be surprised if we looked closely at the soil resources available. To support this statement I would like to refer to a soil transect on the Bel court property of Denison Mines that was mapped by Phil Christie during the soil survey he carried out for Denison this past summer.

The Bel court property lies in the northeast coal block due south of Dawson Creek and due east of Prince George on the B.C./Alberta border at an elevation of between 900 and 2,000 masl. This potential coal property would be mined by an open pit process which would result in the removal of deep geologic strata as well as any overburden material as extensive pit areas are developed. The transect extended from the crest of a mountain ridge in the subalpine environment down to the upper mountain slopes within a potential mine site. On first appearance the entire ridge appeared to be composed of bedrock at or near the surface with only very shallow soil cover interspersed between bedrock outcrops. On closer inspection as revealed by the soil pit excavation at Site 1, the rocky material at the surface was in the form of stone stripes created by the intense subalpine environment and, in fact, there was a soil present that was deeper than expected. It should be noted that on photo interpretation and in the reconnaissance mapping process this ridge was determined to be predominantly bedrock at the
surface. The texture of the soil material ranged from sandy loam near the surface to silty clay over bedrock at a depth between 60-75 cm. This Site 1 pit was located approximately 25 metres downslope from the ridge crest. A soil profile obtained at the Site 2 pit located approximately 25 metres further downslope showed that the soil depth increased to approximately 1 metre. Further soil pit sites along the transect showed a continuing increase of soil depth down the slope up to a depth of 3 metres in the forested area near the timber line. Much of the deposits in which these soils formed would be rated as fair according to Table 2. Within the proposed mine site area many other soil deposits occur which are also potentially suitable for use as cover material and could be considered for stockpiling. This was particularly evident near the mine site. Also an organic soil deposit was mapped in a depressional area in the vicinity of the ridge crest. Much of this organic material, again in the vicinity of the mine site, is potentially suitable for use as a soil amendment.

In my view, to attain a self-supporting vegetative community, the use of existing natural soil materials for covering mine wastes will prove more practical than the expensive, continued support of plant growth using fertilizers and irrigation applied directly to the waste material.

In summation, I believe that by undertaking sufficiently detailed soil surveys and soil sampling programs we will be able to develop reclamation programs for many potential mine site areas throughout the province that will far surpass attempts at reclamation without this knowledge. I recognize that there are many important considerations not considered in this paper. Such topics as materials handling, stability of stockpiles and, maybe most important, the economic feasibility of utilizing soil material as a cover source have not been discussed. These are all matters that will have to be considered in any comprehensive reclamation program.
REFERENCES


DISCUSSION RELATED TO P.A. CHRISTIE’S PAPER

Questioner Unidentified: At what elevation were the soil pits?

Answer: The transect ran from an elevation of 1700 metres at the ridge crest, then down to the timberline to a point 300 metres below it.

Questioner Unidentified: What was the average slope?

Answer: About 15 degrees.

Bill Herman - Pacific Soils Analysis Inc.: Some of the problems associated with vegetation, raised at the 1979 Seminar, resulted from toxicity levels of some of the elements - regardless of whether they were nutrients or not. I'm wondering if anyone has contemplated using organic amendments such as sawdust, as decomposing organic matter has a far greater buffering capacity than mineral soil per se?

Answer: As your Ph.D was in organic soil chemistry, you could probably answer that question better than I. But it does point out why I stress the need for research into the use of organic materials. They are there, and we know that they have these ameliorative capacities. I think they are very important.

R. Hawes - B.C. Research: A major concern is to minimize the areas being disturbed during mining. If you look at the adjacent areas as a source of soils for reclamation, wouldn't you be increasing the area of potential disturbance. In your wetlands example, if you used those soils, would you not also be creating an additional impact on wildlife?
Answer: The wetlands I mentioned were on the mine site and would be lost if the area is mined. I'm not suggesting that we should go out of the mine area and needlessly disturb organic deposits. A gentleman from Cassiar told me that they haul material from up to 20 miles away. Obviously, impacts are associated with the disturbance of natural sites, so it seems to me that if a source of cover material is not available, we're not going to go into the surrounding area to strip topsoil. Such action may well have a horrendous impact. Nevertheless, I have seen many bases where suitably deep unconsolidated surficial deposits do occur which could have been used. You must also consider the Soil Conservation Act and possible difficulties with lands in the Agricultural Land Reserve, but I still think the possibilities are good.

Niel Duncan - Energy Resources Conservation Board, Calgary: Is the comparability of soil material not important? There is a case on the Alberta plains where a lot of money was spent bringing in top-soil. It all washed away in a couple of years, which makes me think that compactability is an important factor.

Answer: That is a significant point. I can only emphasize the need for analysis of these materials. Perhaps mineralogy, excavated fraction analysis, and that sort of thing are also necessary. Other speakers may be stressing this, particularly Susan Ames who will be discussing the soil/spoil interface.